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## Introduction

Climate and geography play primary roles in how the environment is affected by human actions. Dispersal of particles of air, for example, is influenced by wind patterns and rainfall, which in turn are influenced by geographical characteristics. Similarly, the dispersal of ground water is constrained by the particular geology of the site. Thus, data on wind, rainfall, geological, and geographical characteristics are used to calculate the effects that operations at LLNL might have on the surrounding environment. Some history and a description of these data help us understand the relationship of the Laboratory to its climatic and geographic setting.

## Operations

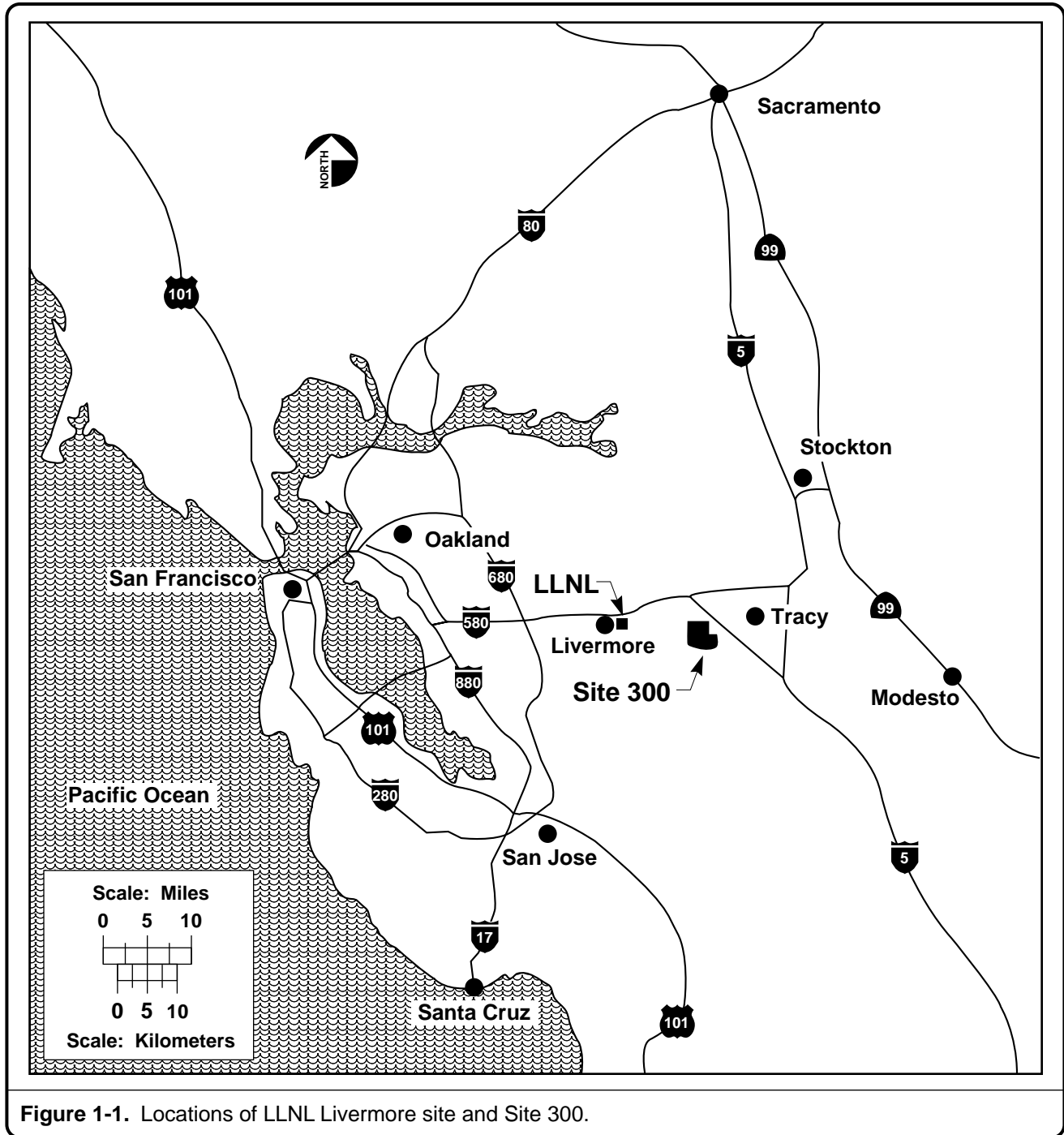
The mission of LLNL is to serve as a national resource in science and engineering, with a special responsibility for nuclear weapons. Laboratory activities focus on national security, energy, the environment, biomedicine, economic competitiveness, and science and mathematics education. The Laboratory's mission is dynamic and has been broadened over the years to meet new national needs.

LLNL is a full-service research laboratory with the infrastructure—engineering, maintenance, and waste management activities, as well as security, fire, and medical departments—necessary to support its operations and nearly 10,000 personnel. At the Livermore site, food service, banking, and limited shopping services are available on site. At Site 300, services include a cafeteria in the General Services Area.

## Location

LLNL consists of two main facilities—the main laboratory site located in Livermore, California (Livermore site), and the Experimental Test Facility (Site 300) located near Tracy, California (**Figure 1-1**). Each site is unique, requiring a different approach for environmental monitoring and protection.

Over 40 years ago, LLNL was founded on the site of a former U.S. Navy training base. At that time, the location was relatively isolated, being approximately 1.6 kilometers from the Livermore city limits. Over the years, Livermore evolved from a small town of fewer than 7,000 people to its present population of nearly 63,000. The economy diversified from primarily agricultural to include light industry and business parks. Within the last few years, low-density, single-family residential development has begun to fill the formerly vacant fields, bringing the city limits of Livermore to LLNL's western boundary.



**Figure 1-1.** Locations of LLNL Livermore site and Site 300.

LLNL's Livermore site occupies an area of 3.28 square kilometers, including the land that serves as a buffer zone around the site. Immediately to the south is Sandia National Laboratories, California (Sandia, California), operated by Martin-Marietta under DOE contract. Sandia, California provides research and development associated with nuclear weapons systems engineering, as well as



related national security tasks. Although their primary missions are similar, LLNL and Sandia, California are separate facilities, each with its own management and each reporting to a different DOE operations office.

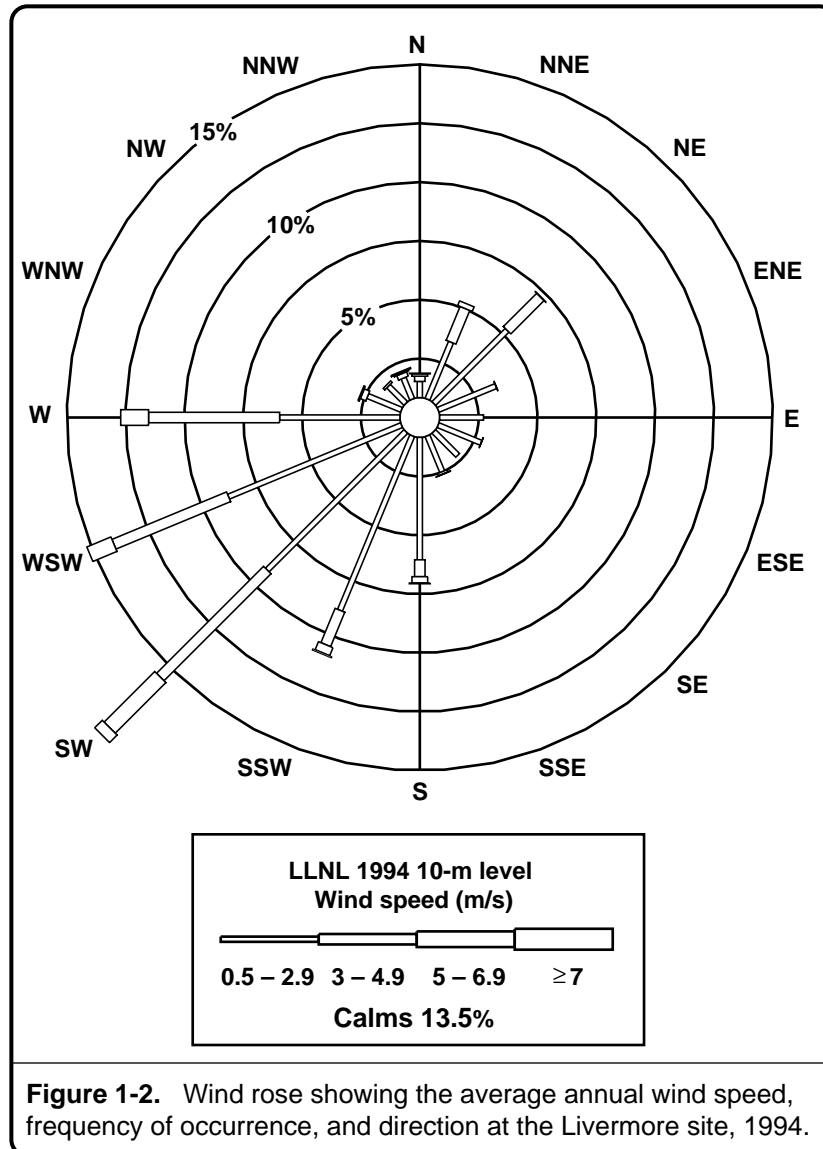
To the south of LLNL, there are also some low-density residential areas and agricultural areas devoted to grazing, orchards, and vineyards; a business park lies to the southwest. Farther south, property is primarily open space or rural ranchettes, with some agricultural use. A very small amount of low-density residential development lies to the east of the Livermore site, and agricultural land extends to the foothills of the intercoastal range that defines the eastern margin of the Livermore Valley. A business park is located to the north, and a 200-hectare parcel of open space to the northeast has been rezoned to allow development of a center for industry.

Site 300, LLNL's Experimental Test Site, is located 24 kilometers east of the Livermore site in the Altamont Hills of the Diablo Range; it occupies an area of 30.3 square kilometers. It is in close proximity to two other testing facilities: Physics International operates a testing facility that is adjacent and to the east of Site 300, and SRI International operates another facility, located approximately 1 kilometer south of Site 300. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300, and wind turbine generators line the hills northwest of the site. The remainder of the surrounding area is in agricultural use, primarily as grazing land for cattle and sheep. The nearest residential area is the town of Tracy (population 42,000), located 10 kilometers to the northeast.

### Meteorology

Meteorological data (including wind speed, wind direction, rainfall, and temperature) are continuously gathered at both the Livermore site and Site 300. Mild, rainy winters and warm, dry summers characterize the climate of the Livermore Valley. The mean annual temperature for 1994 was 15°C. Temperatures range from -5°C during predawn winter mornings to 40°C during summer afternoons.

Both rainfall and wind exhibit strong seasonal patterns. Annual wind data for the Livermore site are given in **Figure 1-2** and **Table 1-1**. These data show that the prevailing winds are from the west and southwest, accounting for 45% of the wind pattern. These wind patterns are dominated by the thermal draw of the warm San Joaquin Valley that results in wind blowing from the cool ocean toward the warm valley, increasing in intensity as the valley heats up. The wind blows from the northeast primarily during the winter storm season. Most of the precipitation occurs between October and April, with very little rainfall during the warmer months. The highest and lowest annual rainfalls on record are 782 millimeters and 138 millimeters. In 1994, the Livermore site received 307 millimeters of rain.



The meteorological conditions at Site 300, while generally similar to the Livermore site, are modified by higher elevation and more pronounced relief. The complex topography of the site significantly influences local wind and temperature patterns. Annual wind data are presented in **Figure 1-3** and **Table 1-2**. The data show that these winds are more consistently from the west-southwest and reach greater speeds than at the Livermore site. The increased wind speed and elevation of much of the site result in afternoon temperatures that are typically lower than those for the Livermore site. Rainfall for 1994 was 217 millimeters.

# 1. Site Overview



**Table 1-1.** Wind rose for Livermore site during 1994 at the 10-meter level.

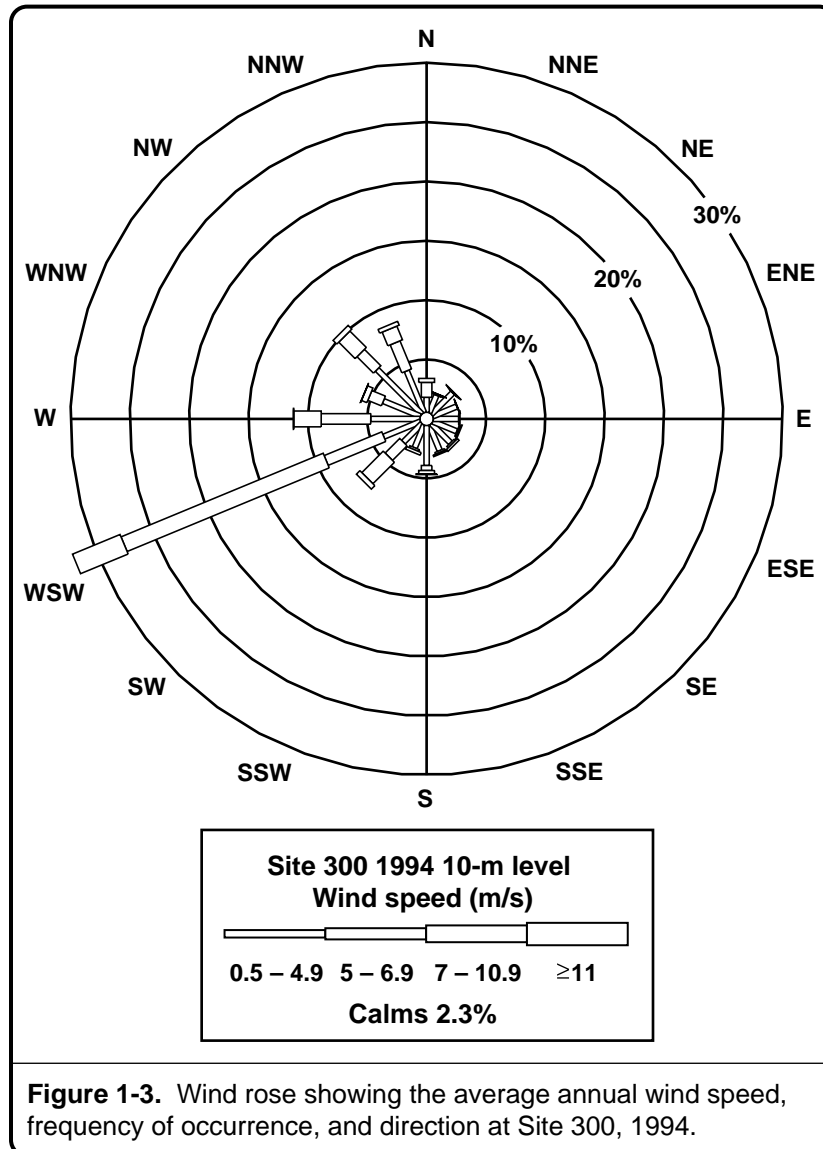
Direction	Livermore Site					
	Wind Speed (m/s)					Total
	0.0-0.4	0.5-2.9	3.0-4.9	5.0-6.9	≥7.0	
NNE	0.84	2.62	1.55	0.21	0.00	5.2
NE	0.84	4.40	2.00	0.01	0.00	7.3
ENE	0.84	2.65	0.01	0.00	0.00	3.6
E	0.84	1.86	0.00	0.00	0.00	2.7
ESE	0.84	1.97	0.01	0.00	0.00	2.8
SE	0.84	1.43	0.00	0.00	0.00	2.3
SSE	0.84	1.65	0.10	0.01	0.00	2.7
S	0.84	5.20	0.72	0.27	0.03	7.1
SSW	0.84	8.02	1.58	0.37	0.06	10.9
SW	0.84	8.32	6.43	3.04	0.45	19.1
WSW	0.84	7.95	5.27	1.11	0.00	15.2
W	0.84	5.11	5.57	1.18	0.00	12.7
WNW	0.84	1.55	0.25	0.06	0.00	2.7
NW	0.84	1.04	0.09	0.00	0.00	2.0
NNW	0.84	0.97	0.20	0.05	0.05	2.1
N	0.84	0.69	0.22	0.10	0.03	1.9
Total <sup>(a)</sup>	13.5	55.4	24.0	6.4	0.6	100.0

<sup>a</sup> Totals are adjusted for round-off error.

**Table 1-2.** Wind rose for Site 300 during 1994 at the 10-meter level.

Direction	Site 300					
	Wind Speed (m/s)					
	0.0-0.4	0.5-4.9	5.0-6.9	7.0-10.9	≥11.0	Total
NNE	0.14	1.60	0.06	0.06	0.01	1.9
NE	0.14	2.55	0.03	0.05	0.01	2.8
ENE	0.14	2.20	0.01	0.03	0.00	2.4
E	0.14	2.14	0.03	0.08	0.00	2.4
ESE	0.14	2.19	0.14	0.08	0.00	2.6
SE	0.14	2.29	0.16	0.20	0.00	2.8
SSE	0.14	2.33	0.15	0.13	0.00	2.8
S	0.14	3.37	0.42	0.29	0.05	4.3
SSW	0.14	2.07	0.17	0.23	0.00	2.6
SW	0.14	2.21	1.73	2.56	0.42	7.1
WSW	0.14	3.35	5.25	18.42	4.34	31.5
W	0.14	4.15	4.17	2.32	0.02	10.8
WNW	0.14	3.38	1.24	0.49	0.01	5.3
NW	0.14	5.34	1.96	1.95	0.44	9.8
NNW	0.14	3.82	2.56	1.25	0.34	8.1
N	0.14	1.27	1.25	0.34	0.00	3.0
Total <sup>(a)</sup>	2.3	44.3	19.3	28.5	5.6	100.0

<sup>a</sup> Totals are adjusted for round-off error.



## Geology

## Topography

The Livermore site is located in the southeastern portion of the Livermore Valley, a topographic and structural depression oriented east-west within the Diablo Range of the California Coast Range Province. The Livermore Valley, the most prominent valley in the Diablo Range, is an east-west trending structural and topographic trough that is bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley floor is covered by alluvial, lake, and swamp deposits consisting of gravels, sands, silts, and clays, at an average thickness of about 100 meters. The valley is approximately 25 kilometers long and averages 11 kilometers in width. The valley floor is at its highest elevation of



220 meters along the eastern margin and gradually dips to 92 meters at the southwest corner. The major streams passing through the Livermore Valley are Arroyo del Valle and Arroyo Mocho, which drain the southern highlands and flow only during the rainy season.

The topography of Site 300 is much more irregular than that of the Livermore site; a series of steep hills and ridges is oriented along a generally northwest-southeast trend and is separated by intervening ravines. The Altamont Hills, where Site 300 is located, are part of the California Coast Range Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. The elevation ranges from approximately 150 meters at the southeast corner of the site to approximately 538 meters in the northwestern portion.

### Hydrogeology

#### Livermore Site

The hydrogeology and movement of ground water in the vicinity of the Livermore site have been the subjects of several recent and continuing investigations. Detailed discussions of these investigations can be found in Stone and Ruggieri (1983); Carpenter et al. (1984); Webster-Scholten and Hall (1988); and Thorpe et al. (1990). This section has been summarized from the reports of these investigations and from data supplied by Alameda County Flood Control and Water Conservation District, Zone 7, the agency responsible for ground water management in the Livermore Valley basin (San Francisco Bay RWQCB 1982).

The Livermore Formation (and overlying alluvial deposits) contains the aquifers of the Livermore Valley ground water basin, an important water-bearing formation. Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Artificial recharge, if needed to maintain ground water levels, is accomplished by releasing water from Lake Del Valle or from the South Bay Aqueduct into arroyo channels in the east. Ground water flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Ground water flow in the basin is primarily horizontal, although a significant vertical component probably exists in fringe areas, under localized sources of recharge, and in the vicinity of heavily used extraction (production) wells.

Beneath the Livermore site, the depth to the water table varies from about 8 to 40 meters. **Figure 1-4** shows a contour map of water table elevations (meters above mean sea level) for the Livermore-site area. Although water table elevations vary slightly with seasonal and year-to-year differences in both natural and artificial recharge, the qualitative patterns shown in **Figure 1-4** are generally maintained. At the eastern edge of the Livermore site, ground water gradients (change in vertical elevation per unit of horizontal distance) are relatively steep,



but under most of the site and farther to the west, the contours flatten to a gradient of approximately 0.003. Ground water flow under most of the site is southwesterly. This flow direction diverges from the generally westward regional flow and from flow patterns demonstrated for the site in the 1980s. This shift in flow direction is a consequence of ground water recovery and remediation in the southwest portion of the site and agricultural pumping. Aquifer tests on monitoring wells in the vicinity of the Livermore site indicate that the hydraulic conductivity of the permeable sediments ranges from 1 to 16 meters per day (Isherwood et al. 1991). This, in combination with the observed water table gradients, yields an average ground water velocity estimate of 20 meters per year (Thorpe et al. 1990). The range in these values reflects the heterogeneity typical of the more permeable of the alluvial sediments that underlie the area.

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### Site 300

Gently dipping sedimentary bedrock dissected by steep ravines generally underlies Site 300. The bedrock is made up primarily of interbedded sandstone, siltstone, and claystone. Most ground water occurs in the Neroly Formation upper and lower blue sandstone aquifers. Significant ground water is also locally present in permeable Quaternary alluvium valley fill. Much less ground water is present within perched aquifers in the unnamed Pliocene nonmarine unit. Perched aquifers contain unconfined water separated from an underlying main body of water by impermeable layers; normally they are discontinuous and highly localized. Because water quality generally is poor and yields are low, these perched water-bearing zones do not meet the State of California criteria for aquifers that are potential water supplies.

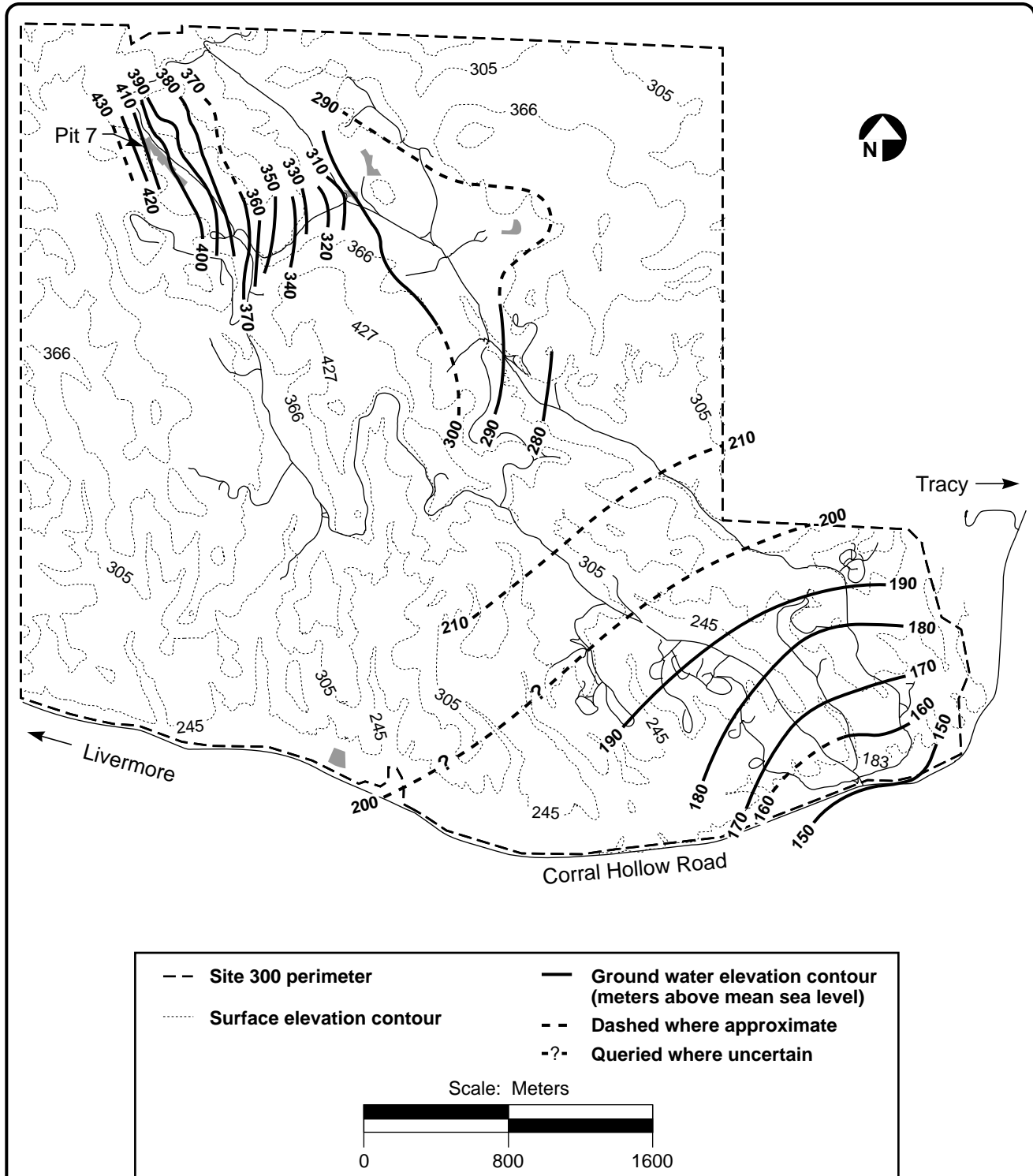
Fine-grained siltstone and claystone interbeds may confine the ground water and act as aquitards, confining layers, or perching horizons. Ground water is present under confined conditions in parts of the deeper bedrock aquifers but is generally unconfined elsewhere.

Ground water flow in most aquifers follows the attitude of the bedrock. In the northwest part of Site 300, ground water in bedrock generally flows northeast except where it is locally influenced by the geometry of alluvium-filled ravines. In the southern half of Site 300, ground water in bedrock flows roughly south-southeast, approximately coincident with the attitude of bedrock strata.

The thick Neroly sandstone, stratigraphically near the base of the formation, contains confined water. Wells located in the western part of the General







**Figure 1-5.** Approximate ground water elevations in principal continuous water-bearing zone aquifer at Site 300.



evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the bedrock aquifers.

Further information on the hydrology of both the Livermore site and Site 300 can be found in the ground water protection information in Chapter 8.

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### Summary

LLNL recognizes the importance of our geology, hydrogeology, climate, and geographical relationship with our neighbors in assessing potential impacts of operations at the Livermore site and Site 300. Each year additional information is gained to allow us to better predict, interpret, and avoid potential impacts. Each environmental medium that is discussed in this document—air, soil, ground water, and vegetation—may be affected differently. The environmental scientists at LLNL take into account the unique locations of the Livermore site and Site 300 to tailor sampling and analysis programs for each medium used to monitor the environment.